GROUP DECISION SUPPORT SYSTEMS

Executive Team-Management Tools For the Military

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The progression of command and control (C^2) systems from message processors into executive decision support devices is the next generation of C^2 development. This evolution is being effected by user-developed prototypes and by the new architecture of Space and Electronic Warfare (SEW).

In a spontaneous manifestation of bottoms-up development, tactical decision aids, prototypes, and other user-developed desktop applications are coalescing into group decision support devices. In this regard, the Naval Tactical Command System-Afloat (NTCS-A) has joined several prototype devices (e.g., JOTS, NIPS, POST) into a comprehensive, LAN-based system.

Simultaneously, in a calculated application of top-down design, SEW architects have proposed networks of workstations supporting the management of sensors, information, electromagnetic-spectrum, and battle-space. This architecture mirrors the group decision-making practices of the Composite Warfare Command (CWC). A preliminary implementation of this design can be seen in the Advanced Track Management System (ATMS) baseline of the Interim Surveillance Direction System (SDS-I).

In both cases, command and control staff members are being equipped with decision support devices appropriate to their domains of expertise. Networking these processors aggregates the work of the staff and creates a decision support system for the group. Systems of this type will displace the C^2 technology of the past to become the Command Decision Support Systems (CDSS) of the future. This article provides a basis for understanding that future.

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Background

Business and academia have studied group decision making and Group Decision Support Systems (GDSS) for at least a decade. The objective of this application has been to foster consensus among *ad hoc* groups of independent executives. In these systems, mechanisms for information input and opinion exchange are more fully matured than the mechanisms for alternatives generation and choice. On the other hand, the development of group support in the military has concentrated on generating and displaying alternatives to a seasoned staff.

Accordingly, one of the key differences between the business and military approaches to group support is the client group itself. The composition, tenure and policies of the group of users is as important a delimiter of performance as are the applications that are emphasized. While all groups of executives seek to assert autonomy over their domains, members of a military staff frequently exercise a virtual monopoly over their areas of interest. Since the practices and consensus mechanisms differ for the two groups, the functions of CDSS and GDSS differ.

The principal services of GDSS are the collection and ranking of ideas and the creation of an anonymous forum for discussion. The GDSS builders start with organizational behavior as an underlying discipline and approach decision making as a group dynamic. The objective is to foster consensus about a single, multifaceted subject.

The CDSS, on the other hand, start with military doctrine as their base and coordinate tactical decisions concerning different areas of warfare (e.g., air, surface, subsurface) The group dynamic of military leadership typically does not require that the decisions of a member of a command staff be negotiated. Rather, these are reconciled, *de facto*, by layering the resulting sets of intersecting directives.

The result is a composite of various warfare-area decisions which are presented to the commander as an ever-changing collage of large screen displays.

Because of this group behavior, CDSS efforts, to date, have centered around creating decision support tools for the individual staff officers and on displaying the results generated by these DSS. The interpersonal and organizational implications for group dynamics are yet to be explored. If CDSS evolution is to avoid the pitfalls[1] of the C^2 experience, analysis and application of these behavioral disciplines is required.

The existing, prototype-based CDSS systems offer ample opportunity for beginning these analyses and this article provides its intellectual basis. It explores the origins of decision support technology and the hierarchical characteristics of decision making. It discusses the military application of single-user systems as tools for alternatives generation and analysis. It offers definition of a group support system for the military (i.e., CDSS) and offers recommendations for implementing behavioral, research in the development of CDSS.

Evolution of the Three Types of Computer-Based Information Systems

Three broad categories of Computer-Based Information Systems (CBIS) have evolved in response to requirements for successively complex output. Those that process transactions are the simplest and those that enhance decisions are the most complex and the newest.

Starting as sophisticated mathematical tools at universities, computers migrated to the lowest level of business to support transaction processing. Then, in response to the needs of midmanagement, the next level of CBIS emerged as computers began aggregating transaction statistics for administrators. Finally, CBIS are be-

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ginning to provide interactive support for decision making at the executive level.

The military use of computers has followed a similar progression but with different application foci. Knowledge of these divergent applications can be an important tool for understanding the newest CBIS and for guiding the future growth of both. Figure 1, illustrates this parallel development by contrasting the business and military applications of CBIS with the products each produces. From this figure, it can be seen that business applications initially were straightforward manipulations of data from financial events (e.g., payroll, sales, inventory). Likewise, the first military applications (though delayed several years while discreet mathematics was perfected) were also dependent on straightforward mathematical processes.

Next, commercial applications focused on presenting summaries of transaction data to midmanagement and the technology of Management of Information Systems (MIS) was created. The military applied CBIS technology to message transmission and the C^2 System emerged. Commercial applications of MIS moved toward tools for simulation and the military perfected its message integration mechanisms.

The legacy of simulators is the Decision Support System (DSS), which offers executives the ability to observe effects of *ad hoc* simulations. Consistent with its historical concentration on the mathematics of accounting, the DSS has been used as a financial planner[2] in business for several years. The military, on the other hand, is concentrating on more esoteric applications of decision support. Disdaining straightforward mathematical applications, the military is applying decision support to information fusion and to the subjective evaluation of tactical alternatives.

Although the field is just emerging,[3] the DSS is sometimes incorrectly called a Tactical Decision Aid (TDA) in the military. The term "DSS" implies a system with libraries of algorithms;

FIGURE 1. The Evolution of Computer-Based Information Systems

Generic CBIS/MIL Name	Commercial Application	Military Application	CBIS / MIL SYS Output
Decision Support Systems / Tactical Decision Aids (ca. 1985)	Financial Planners	Tactical Command	Financial Plans / Battle Plans
Management Information System / C2 (ca. 1975)	Summary Reports	Message Processing	Budget Synopsis / Message Fusion
Transaction Processing System/Sensors (ca. 1965)	Payroll Processing	Weapons Control	Paychecks / Projectiles

FIGURE 2. The Hierarchical Characteristics of Decision Making

Management Activity	Activity Orientation	Data			Decision			CBIS Tool
		Sources	Format	Currency	Situation	Process	Criteria	
Mission Management (Commander)	Achieve Mission Goals	National	Correlated	Non-Real-Time	Unique	Unstructured	Satisficing	DSS / TDA (CDSS ?)
Task Management (Watch Officer)	Allocate & Employ Resources	Mixed Sources	Fused					MIS / C2
Operational Control (Enlisted)	Decipher Sensor Data	Sensor	Detailed	Real-Time	Recurring	Structured	Optimizing	TPS / SNSR

whereas, TDAs tend to be unique singular algorithms. There is library of TDAs at NADC Pennsylvania where users can obtain configuration controlled programs for use with navigation problems. Exemplified by the Electronic Warfare Commander's Module (EWCM), military DSSs employ abstractions that are not found in the mathematics of financial DSS. These methods of qualitative analysis and the formulation and evaluation of choices offers considerable challenge.[4] This is particularly so in areas of organizational and human behavior where the process of decision making is poorly understood.

Hierarchical Characteristics of Decision Making

Not surprisingly, the hierarchy of computer-based information systems is strikingly similar to the structure of organizational decision making. Figure 2 projects the three types of computer-based information systems onto a typical military hierarchy. The left side shows the management activity of a command hierarchy juxtaposed against the information management tool with which they are performed (right side). The middle three columns illustrate: (1) the management activity the user is performing while applying his CBIS tools; (2) a description of the data used by the CBIS; and (3) the parameters of decision making within which decisions must be reached.

As one ascends the hierarchy of management activity and tools, the data from which decisions must be made become less defined and less current. At the transaction level, (e.g., a radar) the information for making a decision is specific and generally real-time. At the opposite end of the hierarchy, upper management deals with information that is non-real-time, has been collected from many sources (i.e., correlated), and originates at locations outside the command. Similarly, the parameters within which decisions must be made become less definitive as one ascends the management hierarchy. The structured, repetitive, optimized decisions the operator makes are replaced by decisions about unique situations that the commander must make using unstructured processes (e.g., instinctively). More often than not, these decisions are made using a decision criteria known as "Satisficing."

This point is easier to grasp in counterpoise with the lowest level of decision making: The bulk of organizational data originates at the operator (i.e., the transaction) level. Here succinct, well-defined optimization criteria, discreet parameters, and well-known solution techniques can usually be solved with linear algorithms. Since this type of computation lends itself to computer modeling, it is not surprising that the transaction level was the first to be automated.

At the level above the operator, where methods of solving the problem are less structured, decision making algorithms are more obscure and descriptive modeling is common. In business, this type of midmanagement decision is often couched in terms of performance differentials (e.g., "...10% above FY '90 consumption levels for...."). The comparable military system, the C[2] system, generally does not offer such modeling.

As has been observed, the origins of C[2] led these systems to mature along a path more attuned to message processing and retrieval than to data summarization. Tracking algorithms and data correlation models have been built into latter-day C[2] systems such as the Flag Data Display System (FDDS). Military leaders should learn to use these applications as tools of analysis rather than for the "truth" of their output.

At its most sophisticated, the decision process is unstructured. Its selection criterion are more attuned to the time constraints associated with making a choice than to the confidence in those decisions. The DSS is a tool for individual decision makers and serves this type of choosing. The circumstances of these decisions are unique and the processes of selection are primarily intuitive. They are typically the prerogative of people who have considerable organizational authority and autonomy in their actions.

The hierarchical structure of organizational decision making complements the history of computer-based information systems. Likewise, an appreciation of the functions of an individual DSS presages the definition of the emerging CDSS application.

DSS: The Single-Person Decision Tool

The DSS, a device that supports a single decision maker, has been defined as:

> A man-machine couple that facilitates the incorporation of experience and instinct in decision-making. It allows the application of *ad hoc* simulations as a medium for hypothecation

('what if-ing?') and automated goal-seeking in the solution of complex, non-structured problems.[5]

Understanding these systems requires an appreciation of the intellectual impetus they can provide. The utility of decision support is the stimulation that successive iterations of machine-generated data can provide to the creativity of the human partner of the man-machine couple. In such a partnership, the function of the machine component is data recall and *ad hoc* data manipulation.

Data manipulation involves the selective use of applications modules (e.g., Markov Analysis, Filters, Spectrum Prediction) and the choice of models is the contribution of the human component. This choice is based on human insight and experience and upon the operator's interpretation of the latest iteration of the data. The breakthrough that DSS portends is the enhancement of the synergy between the optimal capabilities of each of its man-machine components. The use of DSS requires enculturation, as the users of existing prototype-based systems are beginning to appreciate.

The basic components of a generic DSS are illustrated in Figure 3. This illustration suggests a standard set of operational processes and a customized set of application modules. This design permits standard man-machine interface and operations while providing each warfare specialist with a unique set of applications modules.

Communications, text and graphics display, screen processing, a rule-based expert system, model-base management system, and database management modules should all be standard modules. Sets of applications programs for management of the electromagnetic environment, sensors (i.e., undersea, surface and space), tracking, information fusion, data correlation and intelligence filtering should be available optionally.

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As illustrated, centralized database and model-base facilities host the common data and the library of applications modules. Model-base management facilities,[6] a new software management process for joining the input and output of dissimilar decision aids, will most probably be required.

Toward a Definition of Multi-Person Decision Support Systems

Group Decision Support System (GDSS) development, generally sponsored by university research, emphasizes facilitation of the decision process within a group. This work is slowly developing a taxonomy of group decision support but, with the possible exception of Kraemer, it generally neglects the military applications. This section briefly explores the emerging taxonomy as a foundation for an initial definition of CDSS.

Academic publications generally treat group decision support as follows:

> ...Integrated computer-based systems which facilitate solution of semi- or unstructured problems by a group that has joint responsibility for making the decision (Gallupe, 1985), and...the application of information technology to support the work of groups with a focus on improving group performance and organizational effectiveness (NFS Working Group). Vogel observes: Overall, GDSS are now recognized as supporting searching for alternatives, communication, deliberation, planning, problem solving, negotiation, consensus building, and vision sharing, as well as decision making for group members not in the same room at the same time.[7]

These perspectives appear to envision embedded decision aid modules for use in "what-if'ing" but it is not clear from the literature that they do so

FIGURE 3. A Generic Decision Support Workstation

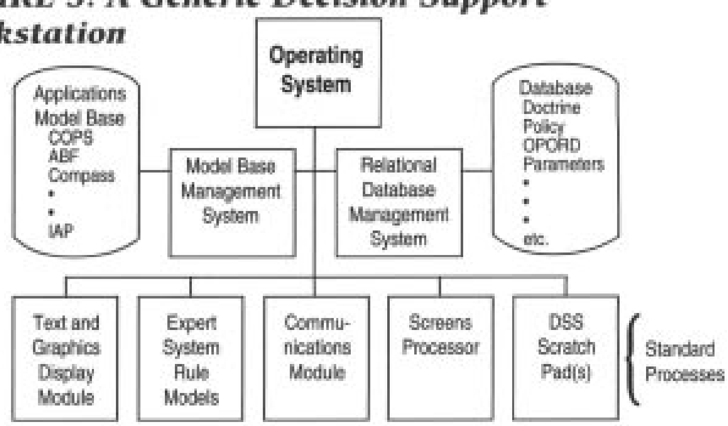
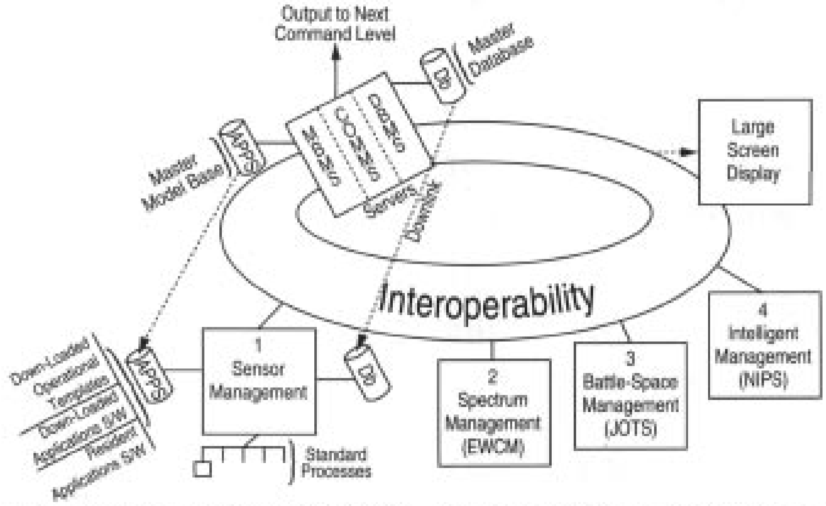


FIGURE 4. A Network of Integrated Workstations



to the same extent as military CDSS. Pinsonneault and Kraemer offer a further classification. They differentiate systems that support intragroup communications, Group Communications Support Systems, from those that support group decision making (i.e., GDSS).

It is their definition of the GDSS device that is most useful because it closely approaches the salient aspects of military applications:

> ...those systems that attempt to structure the group decision process in some way...can support member's individual decision processes through decision models. This basically corresponds to applying Decision Support Systems (DSS) to groups without supporting the group process per se. Here the technology supports [the] decision processes of individuals working in a group.[8]

This is a more appropriate description for the military. As we have seen, the command structure of a battle staff diminishes the need for consensus mechanisms. Also, the decision aids in existing applications tend to emphasize user-machine interaction and recursive calculation without regard for group participation. The Tactical Flag Command Center, a C^2 system that is being upgraded with new tracking and correlation processes, appears to conform to this definition.

The CDSS prototypes that are available also appear to support the definition. Figure 4 is based on the ATMS model and shows independent workstations distributed across a network controlled by database, communications and model-base servers. The workstations represent existing prototypes for the management of (1) Sensors, (2) Electromagnetics, (3) Battlespace, and (4) Intelligence.

This illustration shows applications software, representing tactical decision aids and operational doctrine, being provided to the workstations from a central repository (i.e., the model-base). This could occur on an *ad hoc* basis according to the needs of each warfare-area staff member and are called Optional Application Tapes (OATs) in the "Unified-Build" of JOTS. Recognizing that members of a Command Staff are experts in their warfare-areas, some might prefer to supply their own personal library of applications (e.g., floppy diskettes). These might contain the algorithms and applications modules that were used during training or on other staffs. The model-base management system will accommodate such a scheme. Finally, a large screen display (i.e., the commander's console) represents the military integration medium in which the decisions of the warfare staff are reconciled.

The various similarities between GDSS and CDSS suggest consistency in the research approach to group support. However, the differences between business and military leadership suggests a more interesting possibility. As a comparator, the military rank structure and staff processes (e.g., "management by exception," "silence means consent") can offer an interesting research counterpoise to existing academic research into consensus management. This cross-comparison will accelerate technology transfer between the GDSS and CDSS technical approaches.

Guiding the Development of CDSS with Operational Analysis

Existing CDSS are principally aggregates of user-sponsored decision aids that are being back-fit into existing command and control suites. As collections of user developed devices, the modules are relatively self-contained and provincial. Interleaving the decisions that are facilitated by these tools is effected (presumably) by the delimitation of the warfare-areas and by the ultimate authority of the senior officer.

Accordingly, existing CDSS are simultaneously groups of individual DSS workstations and a single tool for a commander. Notwithstanding the goals of leadership precepts, the commander manipulates these elements according to behavioral considerations (among other things). These interpersonal mechanisms should be implicit in the design of the CDSS but they are not. Speaking of contemporary systems development efforts, Huschheim observes:

> *Research into IS failure has concluded that the primary cause of failure is the lack of consideration given to the social and behavioral dimension of IS....A growing num-*

ber of researchers suggest that information systems are more appropriately conceived as social systems which rely, to a greater and greater extent, on new technology for their operation.[9]

The spontaneous evolution of CDSS, like the eruption of C^2 from its origins in message handling, neglects this important consideration.

These behavioral tactics come into play in various potential CDSS domains. One domain is the intelligence field where emphasis on the integration of intelligence materiel into the platform command process is increasing. As CDSS emerge in response to the perceived need for closer coupling between the platforms and information sources (including sensors), operational studies could help to achieve organizationally workable linkages.

Under the SEW concept, command systems are under consideration that support new ASW tactics at as many as three command echelons (e.g., the Theatre/Region/Sector). To be useful across so broad a management spectrum, information fusion and data correlation requires a significant amount of judgmental activity. As this implies human interaction with the data as it matures into information, it is a mandate for anticipating the effect of human behavior upon choosing. Clearly, organizational characteristics such as authority and procedures also will impact this process.

Finally, systems have been built traditionally from a full knowledge of the practices and procedures under which they will be employed. At present, the operational and command relationships of the new ASW and SEW prosecution mechanisms are not yet established. What *is* apparent at this time is that combat decision support will require systems that have a decentralized architecture of distributed, parallel processes operating in an environment of intensely interactive command. This will demand a higher level of interpersonal interaction among remote participants than has yet been achieved anywhere. Without *a-priori* consideration of the command relationships, communications channels are likely to be flooded with irrelevant coordinating data.

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The CDSS that will respond to these challenges will be distributed systems whose operator-machine components process-in-parallel and decide-in-concert. Spatially distributed teamwork in manufacturing information is increasingly important and mechanically harder to achieve. Behavioral and organizational considerations are a major factor in the operation of such distributed systems and can be expected to become a major aspect of the new designs.

A new Navy laboratory, which is demonstrating collections of fleet prototypes,[10] has the potential for investigating these new concepts of information integration. Through the studies at this center, the definition of teamwork mechanisms for information integration can become an important advance in the development of CDSS.

Endnotes

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